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ON THE ANALYSIS OF AUDITORY MEMORY CONSCIOUSNESS¹

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¹The work on this study was done at Clark University during the academic year and summer of 1906-07. The experiment as originally planned not being completed, the report of the results has been postponed in the hope of carrying out the experiment as at first intended. Change of circumstances, however, has led me to take up other investigations and I offer the results now as they stand. I wish to express my indebtedness to the Clark University authorities for supplying the rather expensive special apparatus required and for the liberal opportunity given to carry out the work, and to my observers,—Dr. W. F. Book, Dr. H. L. Brittain, Dr. W. L. Guard, Dr. J. Morse, Dr. G. Ordahl, and Dr. J. H. White,—for their careful and expert work.

I. INTRODUCTION.

A. *Aim of Study.* The general aim of this study has been the same as in preceding ones on the analysis of visual memory.¹ This is to determine the conscious processes that enter in memorizing and in recalling given sensory material, together with the description of their character and function. It has been discussed sufficiently in the former studies and will not be considered further here. In the analysis of auditory memory, however, a special difficulty is met in determining the detailed character of the auditory imagery and the changes it undergoes with the lapse of time and other conditions. This is the difficulty of describing a sound, or its auditory image. Drawings and verbal description may quite accurately portray size, shape and color in visual memory, but there is no correspondingly adequate means of describing in detail the durations, rhythms, and variations in pitch and intensity of even a very simple sound. The present results on the nature of the auditory imagery and the changes it undergoes are therefore of a somewhat general character only. On the other hand, the method has been quite adequate for determining the presence, nature and function of the non-auditory processes in learning and in recalling the auditory material. Our main effort will be directed to the description of these.

B. *Method and Procedure.* It was desired to study auditory memory under conditions that approached as nearly as possible those of every-day experience. This required means of reproducing at will verbal discourse and the sounds of more or less familiar things in their true character. The graphophone method was finally chosen as the most satisfactory.

The experiment falls into two parts. The material for the first part consisted of verbal discourse; for the second part groups of sounds of familiar things were used. For the verbal discourse five descriptive records were so chosen as to range from a simple monologue to quite complex scenes in which several persons are heard.² For the second part of the experiment two groups of seven sounds each were made up. These were cut out of Edison and Columbia cylinder records. The seven small rings containing the sounds wanted for a

¹ See "On the Analysis of the Memory Consciousness: A Study in the Mental Imagery and Memory of Meaningless Visual Forms". *Psych. Rev.*, 1906, and "On the Analysis of the Memory Consciousness for Pictures of Familiar Objects." *Am. Jour. Psy.*, 1907.

² The following are the records that were used for the verbal discourse: Edison records: 1. McKinley's address at the St. Louis Exposition. 2. Waiting for the Dinner Horn to Blow. 3. Closing Time at a Country Grocery. 4. Two Rubes and the Tramp Fiddler. 5. Louis and Lena at Luna Park.

group were then stuck together again, making a new cylinder record.¹ A scale graded to a hundredth of an inch was fastened to the front part of an Edison machine. A pointer and magnifying lens fastened to the reproducer arm travelled in front of the scale. With this arrangement a little practice was sufficient to enable the experimenter to drop and raise the reproducer so as to pick from each ring just the sound that was wanted and no more, while the observer listened to the group. The substitution of a high grade alternating current motor for the spring motor of the machine, and special ear tubes with sound modulating attachment and means of regulating the intensity completed the equipment for presenting the auditory material.

For the verbal discourse the procedure was as follows. A descriptive record was heard two to three times at the first sitting and not again later. It was recalled four times with full introspective description of the process. The first recall was immediately after hearing, the second to fourth with one, three, and six weeks intervals, respectively, between two successive recalls. Three observers participated. With the groups of familiar sounds three series of experiments were made. In the first series the sounds were heard twice in immediate succession with immediate recall. It was found that two presentations were just sufficient to induce the recall of all, without hesitation, immediately after hearing. Four weeks afterwards the character of the sounds had been entirely forgotten. The second series was then taken with the same sounds and the same three observers, in the same manner as in the first series, excepting that the sounds were now presented three times in immediate succession. In the fourth series three new observers heard the same sounds four times in immediate succession, the procedure being otherwise as before.²

¹Group I consisted of the following sounds: 1. Ringing of a bell. 2. Song of an English Wren. 3. Snare Drum. 4. Crow of a bantam rooster. 5. Lowing of a cow. 6. Laughter. 7. Bugle call—taps. Group II consisted of: 1. Cheers of a crowd. 2. Bugle call—assembly. 3. Peep of a chick. 4. Steamboat whistle. 5. Call of a peacock. 6. Bellow of a calf. 7. Bark and snarl of a dog.

²This constitutes the series with the familiar sounds so far as their results will for the most part be reported at present. In the actual conduct of the experiment, however, three recalls were made in the first series, one immediately after hearing and the second and third with one and three weeks, respectively, between successive recalls. The sounds were not presented again after the first sitting. The second series followed immediately on the conclusion of the first, and the sounds were presented three times a sitting for four successive days, with recalls on the first and fifth days. In the third series the sounds were presented four times a sitting with two sittings a day, continued

The sounds of a group were always presented in the same order, with ten to fifteen seconds intervening between successive ones. The following was then required of the observer: (1) A general, semi-passive recall in which he was required merely to name the sounds and give the order of the different kinds of processes that entered. He was asked not to stop to recall anything further about them. (2) His observations on his manner of memorizing the sounds. (3) The recall of each sound, one at a time, as vividly and completely as possible, giving his observations on the order of the different processes entering and on their nature and function in detail. (4) Next he measured off by means of a noiseless switch key what he thought was the duration of the sound, repeating the measurement three times in immediate succession,¹ and gave his observations on the mental processes in this measurement of the duration. (5) After the conclusion of a series with a group of sounds, each observer measured the duration of each sound while listening to it, in order to determine its actual duration plus the observer's individual reaction time. The main attention and time was given to the third of the above requirements.

II. ANALYSIS FOR AUDITORY VERBAL DISCOURSE.

A. *Factors in the Recall.* I shall consider first the manner in which the words and other sounds heard in the descriptive records were recalled. There were three distinct ways in which this was done. First, the auditory imagery of the words appeared at once without any process preceding as an aid to its recall. Second, concrete visual imagery of the persons and things appeared first as a means of recalling the words. Third, the words were inferred from the context as already recalled. The first way needs no further description.

1. Character and use of the Visual Imagery. While the observer listened to a record he visualized the persons and scene

for four days. The recalls followed immediately after the first sitting of the first day, and preceded immediately the presentation in the first sitting on the following days. The object of the repeated recalls in the first series was the same as in the repeated recalls for the verbal discourse to be described below. The object of the repeated presentation in the second and third series was to determine what changes would thus be brought about in the manner of learning and of recall. As regards the recall, the effect of the lapse of time and of the repetitions of the presentation was not enough to be conclusive. All the figures and tables given in the present report are taken from results of the immediate recalls of the first sittings only. But the introspections of the observers for the later sittings are also taken into account.

¹The key was set in circuit with an ordinary stop-watch and electro-magnet whose attached lever started and stopped the watch as the key was turned in and out.

suggested in much profusion and detail. The details of dress and appearance of persons, their movements, facial expressions, and their surroundings were sometimes visualized in a manner so complete as to seem to leave out but little that would have been supplied if all had been actually present and seen as well as heard. This visual imagery played a very significant part in the recall of the words and other sounds heard. It frequently appeared simultaneously with or followed the auditory imagery, but it was difficult to determine its function in such cases. We shall consider it mainly only so far as it preceded the auditory imagery.

In all but the immediate recalls of a record the first thing that came to mind was as a rule visual imagery. The general setting was visualized, including the persons and the things suggested, their relative positions, and the arrangement of the general surroundings. Sometimes these would be reviewed in much detail so that a remarkably minute description of the appearance of persons and things could be given from this visual imagery. The clue to the recall of the words was sought in it, while all auditory imagery might remain absent for several minutes. With the recall of the first phrase or sentence this visual imagery dropped out for the most part. A very vague and incomplete visual sketch of the scene might remain in the background of consciousness, with a clearer focus that was immediately connected with the words that were being recalled standing out in detail. But more usually the former was entirely absent after some words were once recalled, and was returned to only when the recall became difficult. Degree of difficulty of recall of the words largely determined the nature and use made of the visual imagery throughout. If very easy, the visual imagery tended to drop out entirely, or, if present in this case, accompanied the auditory imagery simultaneously rather than preceded it. Besides degree of difficulty of recall, the nature of the record determined the presence and manner of use of the visual imagery. Naturally, the verbal discourse suggested visual imagery in different degrees, according to its nature. This difference appeared in the recall. This general manner of behavior of the visual imagery gave to it, when taken by itself, various degrees of continuity, both with reference to its temporal succession and with reference to its representing a connected scene or event.

Besides being an aid to the recall of the auditory imagery of the words, it filled in the gaps left by words that could not be recalled at all. Where the words were entirely forgotten the visual imagery present often supplied the meaning. The actions of the persons speaking, the facial expressions as visualized indicated what they were saying, especially what replies

were given to specific questions for which the words had already been recalled in auditory terms. But this filling in with visual imagery where words could not be recalled occurred even when no meaning was supplied with it. Such was the case when a person was visualized as finishing a sentence, or replying to a question, the observer seeing the lips move and the gestures in this visual picture, without any knowledge of the content of the forgotten words. Usually the observer would know fairly definitely the length of the forgotten remarks, but no more, from this visual imagery. This function of filling in the gaps so as to make a continuous and connected account of what was recalled came particularly to the fore when the recall of the words was very fragmentary so as to become confused and the order of remarks lost. In such cases the visual imagery was used to straighten out this confusion and to determine where each remark and phrase belonged.

2. *Inference from the Context.* I call the observer's determination of what the words were from what was already recalled an inference from the context. This process was peculiarly prominent. The nature of the introspective reports indicates that the observers were often not aware that this was the procedure, instead of real recall. But special questioning at such points usually revealed the true process. A definite quantitative statement cannot be made from the present data. But they justify attributing about a fourth, on the whole, of what was reported as recalled to this sort of inference. The descriptive records that were used were favorable to inference as a means of recall. Since all but one presented conversations between two or more persons, questions and answers were both readily inferred when either had been definitely recalled. This was often equally true of any preceding remark when the following one was already known. These inferences were made in two ways. (a) They were made from words that had been recalled, from the verbal context. (b) From the visual imagery. The first needs no further description. The second was apparently the more prominent. The remarks made were inferred from the actions, attitudes, expressions of the persons speaking, as visualized. Obviously, when this visual imagery was quite complete and connected, this could be done readily and correctly. That it might play a large rôle will become clearer after a description of the character of the auditory imagery and the changes which both visual and auditory imagery underwent with the lapse of time.

B. *Character of the Auditory Imagery.* The character of the auditory imagery presented three different aspects: (1) It varied with reference to the completeness with which a sentence was recalled directly in auditory terms. (2) It varied with

reference to the degree in which the words were imaged in the quality of the individual voice. (3) Imagery of the voice in its true character sometimes appeared without the recall of any words.

1. Degrees of Completeness. It might have been supposed that the sentence, or part of it that independently suggested meaning, would always have been the unit of recall. This was not the case. The different remarks that had been heard were recalled in fragments much oftener than as a whole. The auditory imagery of certain words or phrases would flash out first, often remaining isolated from any further recall or any meaning for some time. With this for a start, the remainder would be filled in until the sentence was completed and recognized as correct in meaning and in words. A single sentence therefore frequently embodied all the different ways of recall, direct recall in terms of auditory imagery, the auditory imagery brought in associatively by preceding concrete visual imagery, or brought in by inference from the verbal or visual context. The amount recalled directly in terms of auditory imagery varied from the entire absence of the latter to the recall of all the words in this direct way.

2. Differences in Quality. The auditory imagery for the words recalled was of several different forms. (a) In some cases the words would ring out clear and intense, minutely in the character of the individual voice in which they had been heard. The imagery then approached the perceptive quality characteristic of all vivid recall. (b) As frequently the individual character of the voice was entirely absent in the imagery. The words would still be imaged distinctly, but in a sort of characterless form, resembling the voice of one no more than of the other person heard. Between these two forms all grades naturally appeared. As was the case with most of the records used, two of the voices in each contrasted quite strongly as bass and tenor. Perhaps the most frequent form of the auditory imagery was that in which the bass or tenor was still recognized, but not the particular bass or tenor concerned. (c) A third class of words is to be added; words that were reported as recalled without first clearly imaging them. The process here was similar to that of ordinary conversation, when sentences are formed without any definite auditory imagery preceding the spoken words.

The manner of recall was characteristic of these forms of auditory imagery. The first was usually recalled directly, sometimes suggested by preceding visual imagery, but never the result of inference from the context. The second was largely recalled directly, about as frequently suggested by concrete visual imagery, and in some cases preceded by infer-

ence. The third was solely a product of inference from the context.

From both the form of the imagery and the manner of its recall it might be expected that certainty as to correctness would be greatest for the first and least for the last. In the main this was the case, but with very frequent exceptions belonging to the second class. Words that were distinctly imaged in auditory terms, but without the individual character of the voice in which they had been heard were very often regarded as correct with as great certainty as were those of the first class.

3. Imagery of the Voice without Recall of the Words. An interesting phase of the auditory imagery appeared when in the recall of a sentence the voice was heard to continue beyond the point where the words were recalled. This was not an occasional occurrence, but rather the rule for sentences that were recalled in a fragmentary fashion. The nature of this imagery was by some of the observers compared with hearing voices at a distance, which may be recognized as the voices of certain friends, without being able to understand what is being said. In the case of this auditory imagery the individual character of the particular voice was quite often very clearly recognized. In it was also reproduced the accents and rhythms, so that the number of words that could not be recalled could sometimes be accurately stated. Undoubtedly this imagery was some aid to the recall of the missing words when these were later recalled, but there were numerous instances in which the middle phrase or so of a sentence was auditorily imaged with the beginning and end filled in with this auditory imagery of the voice quality alone as the final result. The latter might be accompanied by visual imagery of the person, moving lips, facial expression, etc., from which something of the meaning might be gleaned.

C. *Changes with the Lapse of Time.* It will be remembered that there were four recalls for each record, and that the time intervals between successive recalls were one, three and six weeks, respectively, the first being immediately after hearing a record. For these intervals the greatest changes occurred between the immediate and the second recall; and contrasting the first with the last recall showed in every case a peculiarly striking transformation in both the manner of recall and in the final result, the auditory imagery of the words. We may consider first the changes in the total process, the factors entering to produce the auditory imagery.

1. Changes in the Visual Imagery. We have to deal with changes in the amount and detail of the visual imagery, in its temporal continuity and associative connectedness, in its func-

tion, and in its clearness and vivacity. This will be done mostly by contrasting the immediate recall with the last two. In the immediate recall the visual imagery was not constantly present. It came in at special points, which were at the beginning, or where the words suggested changes in the scene or action, or where the recall was more difficult. It was therefore incomplete and disconnected as regards the action or event it represented. It also very largely accompanied the auditory imagery simultaneously rather than preceded it as a means to its recall. It might seem to have been largely superfluous at this stage. With this incompleteness went at the same time minute detail of another sort. This was of the persons heard in the record, of their dress, personal appearance and action. A large portion of this had apparently no connection whatsoever with what had been heard, but was merely the result of the tendency to complete a visual picture. It could therefore be of service in recall at any time only indirectly, by bringing up those other details of the visual imagery that had been directly suggested by the words. The first and prominent change with the lapse of time was in the manner of use of the visual imagery. Instead of accompanying the auditory imagery simultaneously it preceded it as a means to its recall. This change was greatest for the beginning of the recall of a record. In the second recall already, after a week's interval, the visual imagery representing the general scene and action was usually the first thing that appeared. Having once started the recall of the words, the visual imagery might recede again, much as in the immediate recall. For the last recalls this change in function was evident throughout the recall of a record. The visual imagery preceded the auditory in most cases. Other changes were connected with this change in function. In the first place, there was more visual imagery of the sort directly connected with the recall of words. It was at first absent in some places where the words might have suggested it, and it appeared at such places later. In the second place, it was temporarily more continuous and associatively more connected, both being largely the result of the new imagery appearing where it was at first absent. Thus, in the extreme cases, the visual imagery taken by itself represented the whole scene and action suggested by the words, developed in the right order and in a continuous manner. It supplied the whole framework for the meaning of the words.

The new visual imagery that appeared during the later recalls was used as a means to recall words. The unessential visual details, details that had not been directly suggested by the words, did not show the same tendency to change. On the whole, it seems to have been somewhat on the decrease.

The observations were to the effect that some of the unessential details had dropped out, while at the same time the descriptions of the ways in which the persons and things suggested were visualized were, when the observer was asked to describe his visual imagery, often as detailed in the last recalls as in the first.

The visual imagery that was used in the later recalls as a means to recall did not show any decrease in general clearness, but was reported as remaining the same; or, in a few cases, as having increased in clearness. Considering the conditions, this, indeed, was to be expected. Since it had not had its origin in visual perception and was repeated at intervals, there was no occasion for its losing in clearness.

2. Changes in the Auditory Imagery. The changes in the auditory imagery with the lapse of time may be inferred largely from the preceding description of its character, and from the changes in the character and function of the visual imagery. We may follow the course already outlined and consider changes in degrees of completeness, and changes in quality. Naturally, the auditory imagery was most complete, the sentences were recalled in less fragmentary fashion, in the immediate recalls. But several additional observations are to be noted. The later recalls were characterized more by whole sentences being left out rather than by certain phrases or words only of a sentence being recalled. Thus the fragmentary character of the sentences that were recalled did not change so much with time. But the meagreness of this direct recall in terms of auditory imagery when compared with the visual imagery present was always very striking after the six weeks interval. A sentence or two was sometimes all that was imaged in auditory terms without being derived from the visual imagery. Further, the fragments consisting of a few words or a phrase only in the immediate recall were often not completed at all, the meaning being lost. But in the later recalls such fragments recalled in auditory terms were more usually parts of sentences that were filled out in other ways, the words only and not the meaning also being forgotten.

The change of the auditory imagery to a form in which the individual peculiarity of the voice heard is absent is one that has been observed in the recall of nonsense syllables. It is the main change in quality to be noted here. The change for connected verbal discourse, however, seems to be more marked, probably because this individual character of the voice is in this case more vividly imaged at the beginning than it is for nonsense syllables. In the second place, the change occurred much more slowly. Even in the third recall the

voices were sometimes still imaged in their individual character, so far as the observers could judge. We may also note several stages in this change. This will make the complete statement of the forms of the auditory imagery and the order in which the changes from one to the other occurred as follows: (a) The voice is imaged in its individual quality. (b) The voice is imaged as bass or tenor, but without any particular individual characteristic. (c) The voice is imaged in a somewhat characterless fashion. (d) No complete imagery of the voice at all, the sentences being formulated as is usually the case in ordinary conversation.¹

III. ANALYSIS FOR GROUPS OF SOUNDS

Any one who has had his attention called to the matter will have observed the very striking difference in the amount and nature of associated imagery when he is looking at things when they are silent and when he is listening to the sounds they make when he cannot see them. The visual impressions of things have of themselves but a very slight tendency to arouse the memory of their sounds. But when we hear sounds we almost invariably visualize the things that produce them. In the previous study on the memory of pictures of familiar objects there was never the slightest tendency to auditory imagery while memorizing a group of pictures, and auditory imagery entered only in a very few individual instances in the recall of the pictures after long time intervals. How visual imagery enters when the sounds heard are human voices has been seen in detail above. In the second part of this study visual imagery was never entirely absent in listening to the sounds for the first few times, nor in the recalls immediately after hearing them. But this visual imagery does not constitute the only possible associated process that may be relatively absent or abundantly present in auditory perception. We have to deal always at least with vocalization and with other motor processes. This, if present at all in the memorizing and recall of verbal discourse, played such an insignificant part as to escape the observer's notice. But in the case of the groups of sounds both the process of memorizing and of recall was more complex. A brief description of the factors present in memorizing the sounds will throw some light on the analysis of their recall.

A. *Methods of Memorizing the Sounds.* The nature of the

¹For the third form one observer noted that the words were imaged somewhat in the character of his own voice. This suggests that vocalization was probably also a factor in the recall in this case. But whatever part vocalization may have played, it was of such an incipient character as to escape observation.

series of experiments taken in this second part will be remembered from the description already given (pp. 195 ff. above). The methods of memorizing a group of sounds were different in the first series from what they were in the second and third. In the first series the small number of repetitions permitted little more than learning the group as a whole. Only a minor share of the attention could be directed to memorizing the details of individual sounds, if none were to be forgotten altogether. In this matter the observers all followed the plan used by those memorizing visual material. Details were attended to only after the recall as a whole was insured. Associated processes entered at once. For all the sounds that were interpreted at all the visual image of the thing was at once aroused on hearing the sound. While the sound lasted the attention was then divided between the auditory perception and the visual image. In the first repetition of a group immediately after the first hearing an incipient naming of the things, or an incipient imitation of the sound might accompany the hearing. By the third or fourth hearing imitation always entered. The ten to fifteen seconds intervals between successive sounds were used for the recall of what had just been heard. In this recall attention usually went to the names in an attempt to commit to memory the series of names for the group. With the recall of the name, the visual image usually came in of its own accord, while the auditory image entered less readily.

In the second and third series the larger number of repetitions of the presentations made attention to memorizing details possible. The general procedure of the observer changed. The first change was the frequent absence of the visual image while the sound was being heard. In the second place, imitation of the sound, while listening, increased. In the recall during the intervals between successive sounds the visual image was very readily eliminated, and the name disappeared with equal ease. The prominence of auditory imagery increased correspondingly.¹

B. *The Factors in Recall.* 1. *Associative Connections Between Sounds.* Associative connections between two or more sounds were in the present case almost entirely absent, though such connections were very prominent in the memory for pictures of familiar objects. Only one form appeared. This consisted of a classification, two or three sounds being put into a class and fixed by a verbal class description. Such associative connections, however, as a means of recalling any of the sounds as

¹These changes in the manner of memorizing became quite marked in the later sittings of the second and third series where the sounds were heard repeatedly on successive days.

wholes played a very insignificant part. Their function need not be considered further. But before comparisons are made two special reasons for their absence here must be noted. The first lies in the small number of sounds in a group. Such associative connecting was not so imperatively required in order to insure the recall of all. The second lies in the fact that the sounds were presented successively, while the pictures were presented simultaneously. Associative connections between the individual members of a group of stimuli doubtless always suggest themselves more readily when the stimuli are presented simultaneously.

2. The Order of Appearance of the Different Processes. The processes with which we are concerned here are: (a) the auditory imagery, the recall of which is the purpose of the whole; (b) the visual imagery of the things that the sounds suggest; (c) the verbal imagery of the names; (d) the motor processes involved in vocally imitating the sounds and in following out the rhythms with hands, head, and other parts. The function of these factors in the total recall process may be measured in part by the order in which they appear in that total process. This order will give an idea of their relative spontaneity, and hence of the relative ease with which they can serve the function of suggesting auditory imagery. In this only the results of the general, semi-passive recall will be taken into account. When the effort is made to recall the sounds as completely and vividly as possible the order and function of the several processes is quite different. This will be seen later. The following table gives the percentages of the number of times each process held each of the four places, or was absent entirely.

	I ¹				
	1st	2d	3d	4th	Absent
Visual	53	25	15	1	10
Auditory	35	39	29	6	3
Verbal	15	15	0	55	18
Motor	8	22	18	10	44

In taking these figures as an indication of the relative spontaneity of the several processes we must take into account the necessity of using the names of the things for the purpose of describing the process of recall. This brought in the verbal process for the fourth place when otherwise it would probably

¹In those cases in which two processes were reported as having appeared simultaneously each was counted once for that place. This makes the percentages sum to a little more than a hundred for each process, except for the verbal the observation on which was sometimes overlooked.

have been absent in these 55% of the cases. The 18% in which it was absent include the cases in which the observer did not interpret the sound and therefore had no name for it. Aside from this, we see that half the time visual imagery is the first thing in recall, that the auditory imagery is distributed fairly equally over first, second, and third place, that the verbal process comes in either early or last, and that the motor process is most frequent in the middle of the total recall process. It will be remembered that in the recall during the memorizing of a group of sounds more effort was made to recall the names than for any of the other processes. Its relative lack in prominence here is significant as showing how readily a process can serve the function of fixing associated imagery so as to insure its recall and then itself drop out of the recall later.

This comparison of the relative spontaneity of the several processes gives only a rough idea of the relative part each played directly in leading up to the auditory imagery, since each might follow as well as precede the latter. This function of each is seen better in a direct comparison of the relative frequency with which each preceded and followed. The next table gives this comparison in percentages.

	II	
	Preceded	Followed
Visual	55	35
Verbal	24	58
Motor	13	43

It is understood, of course, that these several processes, visual, verbal, and motor might accompany the auditory imagery, simultaneously, or might remain absent altogether in this general, semi-passive recall, and also that any two or all three might in the individual case precede the auditory imagery.

Since in this part of the experiment the object was merely to determine the relative spontaneity of the different factors in the total recall process, no effort was made to get observations on the nature and degree of completeness of the auditory imagery. But it was evident that as a rule only a very small part of the total auditory imagery for a sound was aroused in this way, while the 43% of the cases in which motor processes of imitation followed auditory imagery is evidence that the process of recall did not always stop where it was intended it should. For, as we shall see later, the use of motor processes was the predominant means of recalling details. We may proceed now to a description of the character of these several factors in the recall, and the manner in which they were used to produce

auditory imagery. We shall here consider both the semi-passive recall and the recall of the details of the sounds. In this recall of details the relative usefulness of the several factors is entirely changed.

3. Character of the Visual Imagery and Nature of its Function. From the standpoint of its function, the visual imagery that entered the recall of the sounds follows three types: (a) The visual image of the thing that produced the sound, which is used for the purpose merely of getting the auditory imagery as a whole or for starting the auditory process. (b) The visual image of the thing going through the motions it would make in producing the sound in question. In addition to being used in the same way as the first, it sometimes served the purpose of recalling the details of the sounds. (c) Visual sound analogues, used mainly for the recall of details of the sounds. The first class and its manner of use was by far the most frequent, so that in the semi-passive recall visual imagery was very prominent as an aid to recall, while in the recall of details it was quite infrequently an aid.

(a) The visual image of the thing tended to take on special characteristics that were suggested by special characteristics of the sound. In individual instances this was carried out to quite minute details. But frequently a visual image with such special characteristics to fit the sound in detail could not be found, or at least did not suggest itself spontaneously. In these latter instances what did suggest itself was not ruled out because of its shortcomings. It appeared as a means of recalling the auditory imagery as a whole although the discrepancy between the thing visualized and the sound with which it was associated forced itself vividly upon consciousness. A tendency exactly opposite to that of visualizing in detail was the appearance of only the essential parts of the thing in the visual imagery, the parts that immediately produced the sound or from which it was emitted. Possibly another form of this tendency was given in some cases in which it consisted merely of some sort of visual consciousness of the direction and distance from which the sound was regarded as coming. With the first suggestion of a part of the auditory imagery the visual imagery of this class at once dropped out. It sometimes appeared a number of times again before the auditory process was completed, but in such cases it came in entirely of itself and was of no service. If the observer tried voluntarily to recall it again and hold it, it interfered with the auditory imagery. Usually the latter dropped out at once when the visual imagery was thus attended to.

(b) For the second and third classes of visual imagery the behavior of the auditory imagery when the former was thus

attended to was sometimes quite different. In some cases in which the object was visualized as going through the motions required in making the sound such visualization was an aid to the recall of the details of the sound. These cases were, however, not frequent even when considering only those instances in which they were quite possible. The observer also sometimes stated that its presence seemed to be of no aid to the recall; it merely accompanied the auditory imagery. The possibility of its being used in the recall of the details followed from the fact that in these cases the visual and auditory processes constituted two closely parallel series of changes. A change in position of the moving part was closely associated with a change in the character of the sound. That the visualization of these motions did not always play a part in the recall of details is very likely accounted for by its influence being outweighed by the distraction introduced in turning the attention to disparate imagery.

(c) The visual sound analogues came in less frequently to start the auditory imagery or to recall the sound as a whole, but when present were always used to recall details. Only three of the six observers reported them, but with two of these they were very common, some form being made use of in most cases. These analogues consisted, in the first place, of the visualization of some arbitrary form, marked off somewhat vaguely in the general field of vision by differences in brightness, in a few individual cases colors being introduced. The majority of these forms were cylindrical or elliptical in shape. Others consisted of coils, wavy lines, irregular patches. In addition to their general shape they possessed within further details of form in varying degrees. Likewise, while a difference in brightness marked them off in the general visual field, further differences in brightness and color marked off different parts or areas within them. Finally, either the form as a whole alone, or parts within, were visualized as in motion, or, what corresponded to such motion, the form was visualized as developing from one end to the other. Every detail in form, brightness, color, and motion, was patterned as an analogue to some characteristic in the sound. The two were associated so closely as often to seem to the observer like one process. The details of the auditory imagery were superimposed, so to speak, on the details of the visual, the two developing absolutely simultaneously. The auditory imagery, as one observer put it, was *visual*-auditory. In this way duration, rhythm, intensity, and pitch, were put into visual terms. The auditory part was never present without the visual analogue, but the latter often appeared without the auditory associate. In the latter case much could still be said about the nature of the

sound, and its duration could be indicated quite as accurately as when the auditory imagery was present also. These visual analogues usually appeared without any effort on the part of the observer to recall them. But when attention was directed to the recall of their details it never hindered, but always improved, the auditory imagery.

4. Use of the Verbal Process. Only the names of the things that produced the sounds, and never any verbal description of the details of the sounds themselves were employed. The former could, from the nature of the case, be useful only in recalling the sound as a whole. From the figures in the tables already given we saw that the recall of the name preceded the auditory image in 24% of the cases, and that in 55% of the cases it held last place in the total process. In this 24% of the cases the orders verbal-visual-auditory, visual-verbal-auditory, and verbal-auditory-visual occurred with about equal frequency. But the meagre data do not allow much generalization. For one observer the order was very strongly visual-verbal-auditory. For another the order verbal-auditory-visual was equally prominent. The nature of the verbal process with reference to the kind of imagery involved, gives some additional insight into the part it probably played in producing auditory imagery. When the verbal held fourth place it was nearly always a purely motor process. When the observer had completed the recall he simply found himself incipiently or actually pronouncing the name. There was no visual or auditory image of the name. On the other hand, when the verbal process preceded the auditory, and especially when it preceded also the visual, it was much more likely to include an auditory image of the name. At this point in the recall the observer was not concerned with description and the verbal process would not enter from this cause. There are left, however, some cases in which it followed reflexly the visual image that preceded the auditory.

5. Character of the Motor Processes and Nature of their Function. The motor processes were by far the most important of the several factors in the recall of the details of the sounds. As regards the muscles that came into use, they were of great variety. But we may divide them into two classes on the basis of their function and briefly describe, first, their general character, and then consider the manner of their use. These classes are: (a) motor processes involved in the vocal imitation of pitch and quality, and (b) various motor processes involved in the imitation of rhythm and duration. In the former the same set of muscles were necessarily always concerned, while imitation of rhythm occurred in the variety of ways familiar to every one.

(a) Naturally, the pitch and quality of the sounds could

not usually be accurately imitated. Very rough approximations only were the rule. Certain details of the sounds could be imitated. The rest would be 'slurred over.' This consisted mostly of a stationary tension in the vocal muscles with accompanying regulation of breathing. Sometimes another sound was substituted that was more easily imitated and which resembled the real sound. These substitutions were at times recognized as something familiar, and sometimes as constructions for the occasion. Imitating the sounds aloud was not permitted, but the vocalizing was nearly always much more than incipient. This was shown both by the direct observations and by laryngograph records that were taken on a few occasions. The care taken to imitate the sounds was apparently not greatly affected by the ease or difficulty met. Some vocalization of an imitative character entered in the recall when no sort of approximation even would seem to have been possible.

(b) Imitation of rhythm and duration was on the whole easier than imitation of pitch and quality. It was reported by the observer as considerably more prominent. For the irregular and difficult rhythms slurring over and substitution occurred in quite the same way as for pitch and quality. In like manner the very rough approximation to what was recognized as correct was followed out with as great care as the quite easy rhythms. One general and significant difference, however, is to be noted. In the imitation of rhythm there was a greater tendency to let details drop out, not because they were difficult, but because they were not needed for the purpose for which imitation of rhythm was used most. In this way imitation of the rhythm often became but little more than an indication of the duration of the sound. This consisted usually of a stationary tension in the muscles or of a single long-drawn-out movement equal in duration to the recognized duration of the whole sound. The regulation of the breathing in this way was especially prominent among these cases.

In describing the manner of use of both these classes of motor processes attention must be recalled to the distinction made between recalling the sound as a whole and recalling it in detail as vividly as possible. From the figures given on the order of the processes in the former kind of recall, it was seen that the motor processes preceded the auditory imagery in only 13% of the cases, while visual imagery preceded it in 55%. In the recall of the details of the sound this relation is entirely reversed. We have already seen how the visual imagery usually dropped out in the recall of details. But for *the motor processes in the recall of details* we may state at once as a general fact that they *were a constant and necessary means of producing auditory imagery of a sound in full.* The more they could be

introduced, the more detailed and vivid, the more satisfactory in general would be the auditory imagery. The process was decidedly a *motor*-auditory complex, in which the two factors were even more inseparably united than the visual sound analogue and the auditory imagery associated with it described before. According to the various observations at different times, the auditory imagery would fail to appear if the motor processes were voluntarily inhibited, or if attention was directed to getting the auditory imagery directly; the latter was dependent on the motor processes. To one observer the two seemed like one unitary process, his generalization on one occasion being that: "The vocalization almost *is* the sound. I cannot separate the two at all." Even for the observer who succeeded best in getting independent auditory imagery the latter could not be carried through vividly to its completion, but remained fragmentary and hazy without resorting to vocal imitation. As regards the difference in the function of the two classes of motor processes described, vocalization of pitch and quality and motor imitation of rhythm and duration, it is to be noted further that the two were not independent. While imitation of rhythm was perhaps no great aid to the recall of pitch and quality, the muscles involved in vocalization were often involved in marking off the rhythms and in judging the durations. In the recall of the duration of a sound the muscles used in following out the rhythms were the predominant factor. We may turn now to a special consideration of the recall of duration.

It will be remembered that each observer indicated the duration of a sound as he recalled it by turning a noiseless switch key, and that he also gave his observations on the mental processes involved in making this measurement. The latter will be taken up first. It was found at once that this measurement from memory was not at all a matter of measuring the duration of the auditory imagery. Five of the six observers could not even approach such a degree of control of the total auditory imagery as to make its total duration anything like what they regarded as the duration of the sound. They made the measurements mainly from the motor processes. The auditory imagery was, indeed, entirely absent about as frequently as any was present. In the majority of cases when it was present it was regarded either as of no use at all or as being only of slight aid in judging duration. The details with which the rhythm was followed out varied with the observers and with other conditions. The tendency to slur them over was often noted, so that the duration was judged largely from merely the stationary tension of the muscles, or long drawn out movement, as already noted.

From this analysis of the mental processes involved in measuring the duration from memory, it becomes more proper to speak of the accuracy of the associated motor processes in making this measurement than to speak of the accuracy of the auditory imagery. The next table gives a fair idea of how serviceable these motor processes were for this purpose. It gives the averages for the six observers of the measurements in seconds, of the actual sounds while they listened to them, and for their percentage of error in measuring them from memory.

III

Order of sounds in a group,	I	2	3	4	5	6	7
Duration as heard, Group I,	6.0	7.8	4.1	2.0	2.1	2.2	21.1
Percentage of error in recall,	21	41	33	33	77	17	63
Duration as heard, Group II,	3.4	4.6	1.3	5.4	1.8	2.0	2.2
Percentage of error in recall,	50	50	24	41	35	15	8

The general average error from these figures is 36. That is, these observers in measuring the duration of these sounds from memory during the hour in which they had heard them made an average error of 36%. They were underestimated more frequently than overestimated. Disregarding many exceptions we may state it as a rule that the short sounds were usually overestimated, while the long were always underestimated. The slowness of the motor processes in imitating seemed to be responsible for the overestimation of sounds of less than two seconds duration. Substitutions of other sounds and their imitation for the original doubtless caused overestimation in other cases. The tendency to gravitate towards an average length, a law found to hold true for the intensities of lights as recalled, was probably also present. But no adequate analysis of the causes of these errors in the measurement of duration of the sounds can be made from the present data. The variation in the amount of error from observer to observer, and from sound to sound was very great indicating a high degree of complexity of factors. The main result that is of significance for our present purpose is the fact that the auditory imagery was found to be so much less efficient than the motor processes in estimating the duration from memory, and that with the latter such large errors were still made.

C. *Character of the Auditory Imagery.* The foregoing analysis of the recall process, of the aids to reinstating the auditory imagery, the character and manner of their use, brings us to the description of the auditory imagery itself. Here we meet again the difficulty noted at the outset: there is no adequate means of describing auditory imagery. A few general characteristics of the auditory imagery were determined from the direct observations, and some further inferences

from the observations are evident. Our description will be limited to these.

1. Incompleteness. The characteristic most striking to all observers was incompleteness. What was present in auditory terms seemed to represent only a small part of the sound. If we combine this direct observation with measurements from memory of the sounds we see that the auditory imagery must often have been exceedingly fragmentary. These measurements of the duration were sometimes over 50% too short, but the auditory imagery took up only a small part of this measured duration. Indeed, direct observation in many special cases shows well enough this fragmentary character. We have, first of all, those instances in which the visual analogues or the motor processes were gone through in detail with no auditory imagery present whatsoever. In some of these cases the observer was still able to measure the sound from memory with some fair degree of satisfaction to himself. Statements that only a trace of the auditory imagery, a bare suggestion of it, a mere 'flash', etc., could be obtained were very common. Its presence in such a degree of completeness as to seem to represent approximately all the details of a sound was very exceptional. The rule was that only a fraction of the sound, a fourth to a half, seemed to be imaged in auditory terms.

2. Its Course and Voluntary Control. Second in importance were certain characteristics concerning the course and voluntary control of the auditory imagery. A comparison of visual imagery of forms in these respects makes them the more striking. Its course was decidedly irregular. Certain parts only would come out, a note here and there, or larger part marked off more or less from the rest by its general character. These parts might be recognized as quite correct in quality, and were nearly always definitely placed in the total sound as being near the beginning, or end, or middle. The rest of the sound as remembered would then be represented by other than auditory processes. The means of its control has already been indicated. It was not direct, but through the aids to recall. In the effort to reinstate the auditory imagery in detail attention was not directed to that imagery itself directly, but to the motor processes of imitation, and to certain kinds of visual imagery in some cases. With attention thus directed the auditory imagery seemed to come in of itself if it appeared at all. When started or once obtained, it could not be held or developed by turning attention to it directly. It disappeared at once in spite of concentration, and the aids had again to be resorted to to make it return. As one observer put it, "Without the vocalization the auditory imagery does not run smoothly, the attention does not hold to it; it slips off and the

auditory image is gone." This means of control was employed for the different parts of the sound independently. Auditory details were repeated and modified to get them more correct by repeating and modifying more or less step by step the motor and visual processes for these details. Immediate repetition of the total recall decreased for the time being the ability to reinstate the auditory imagery. With such repetition it became vaguer, more incomplete, and required more attention to the aids to reinstate it. Apparently this is a fatigue effect not at all equally shared by visual imagery. Some auditory imagery sometimes came up more or less independently of motor or visual aids. This might be correct so far as it went, but sometimes it was recognized as wrong. In the latter case the observer often found that he could not control it so as to make it come up correctly. It consisted of short spontaneous 'flashes', belonging equally to easy and difficult sounds. These came in unexpectedly, when attention was not particularly directed to the recall of any detail, or just at the moment when the observer was relaxing his effort to recall. They disappeared at once and could never be reinstated by attempting to do so. The prominence of this kind of auditory imagery varied much with the different observers. For one a series of such flashes for a sound became the guide for directing and re-directing his motor processes by means of which he produced the auditory imagery in detail. Another observer, on the other hand, never reported such imagery.

3. Its Vividness and Quality. No direct measurement of the general vividness being possible, the observer was asked to compare the auditory imagery in this respect with his visual imagery of the things that entered. This comparison easily demonstrated a very great difference between the two classes of imagery. The observer whose auditory imagery was most prominent sometimes stated that it was as clear and vivid as his visual imagery of the associated things. But even for him such vividness was quite exceptional. For the other five the auditory imagery seldom even approximated the visual in vividness. This, indeed, becomes evident enough when we consider the general results given above, and compare them with our general observation on visual imagery.

As regards its general quality, the auditory imagery that was reinstated was of four different classes. These will need no special description. They were as follows. (a) Auditory imagery which included the characteristics peculiar to the given sound, and made it individual, instead of one of a class. For instance, the crow of the bantam rooster would be imaged in the distinctive way as heard, not as representative of the crow of any bantam rooster. (b) Auditory imagery represent-

ing largely only the class of sounds to which the one heard belonged. In these cases the observer was uncertain often as to whether the distinctive characteristics were imaged or not. Many of the substitutions for the original as heard belonged to this class. (c) Sounds considerably different from those heard were substituted, the observer being aware that his imagery represented a substitution, but accepting it as the nearest approximation he could make. (d) Some sort of auditory process which represented merely the general quality of the sound but included no detail or variations in pitch or intensity. This would distinguish the bugle from the whistle or from another musical instrument, for example. The usual statement of the observer in this case was that there was present a certain auditory quality that identified the kind of sound, but this mere quality did not materialize into a definite auditory image. With the exception of the third, as is seen, these are the same classes described for the auditory imagery in the recall of verbal discourse.

IV. SUMMARY OF RESULTS

In the recall of verbal discourse the words were recalled (1) directly in terms of auditory imagery; (2) associatively through visual imagery of the persons and things that the heard words had suggested; (3) through inference from the visual or verbal context as already recalled. The second method of recall was by far the most prominent, and came especially into use at the beginning of the recall of a record, at turning points in the discourse, and at other points where for any reason the recall of the words was difficult.

The character of the auditory imagery varied with reference to (1) its completeness, (2) the degree in which the words were recalled in the quality of the individual voice; (3) imagery of the voice in its true character without the recall of any words sometimes occurred. As a rule only fragments of sentences and phrases were recalled directly in terms of auditory imagery, the rest being filled in by the other methods of recall. Sometimes the words were recalled in the quality of the individual's voice as heard. Usually this individual character was not represented in the auditory imagery while the latter was nevertheless distinct and clear. Sometimes the words were recalled without first definitely imaging them in a manner analogous to the process in ordinary conversation.

Changes with the lapse of time in both the manner of recall and in the nature of the factors entering were greatest from the immediate to the second recall, after a week's interval. Visual imagery, that at first accompanied simultaneously the auditory imagery of the words or followed it, later preceded it and became the means of recall. It increased in amount and

continuity, so that the visual imagery alone presented the whole scene and event. The general clearness and vivacity of the visual imagery remained about constant throughout the several recalls.

The total amount recalled in auditory terms decreased markedly, leaving sometimes only a sentence or two that was thus recalled after the six weeks' interval. But the fragmentary character of the sentence recalled at all did not increase much. The quality of the auditory imagery showed progressively the following stages of changes. (1) The voice was imaged in its individual quality. (2) It was imaged as bass or tenor merely. (3) It was imaged in a somewhat characterless fashion. (4) No definite complete auditory imagery at all appeared before the words were formulated and stated in the recall.

The processes entering in memorizing a group of sounds changed with the repeated presentations. During the first presentation attention was well divided between the actual sounds and the visual imagery they aroused. The first repetition or two next brought in the processes of naming the sounds and of vocally imitating them. With still further repetitions the visual imagery and the naming readily dropped out, the motor processes of imitation increased for a while, but tended also to drop out finally.

In recalling the sounds in a semi-passive way without any effort to recall them in detail or vividly, visual imagery appeared first in 53%, auditory imagery in 35%, the name in 15%, and motor processes in 8% of the cases. The auditory imagery was preceded by the visual in 55%, by the name in 24%, and by the motor processes in 13% of the cases. This shows the relative spontaneity of the different factors in the total process of recall, but not at all their relative value as aids to the recall of the sounds in detail.

According to the manner of its use, the visual imagery was of three kinds. (1) The visual imagery of the things that produced the sounds, used solely to recall the sounds in a general way or to start the auditory process. Attention to it for the recall of details was detrimental to the recall. (2) Visual imagery of the things going through the motions they would make in producing the sounds. This was used like the first and also sometimes to recall details. (3) Visual sound analogues, consisting of arbitrary forms, sometimes including colors, whose characteristics were patterned after characteristics of the sounds. These were used mainly for the recall of details. The first class was by far the most frequent.

Only the names of the things and never any verbal description of the sounds entered the recall. From the nature of the

case, therefore, the verbal processes present were never an aid to the recall of details.

The motor processes used in imitating the sounds were by far the most important factor in the recall of details. They were *inseparably connected with the effort to recall a sound vividly and minutely*, and constituted a necessary means to the same. They were the basis for measuring the duration of the sounds from memory, in which process all auditory imagery was entirely absent about as frequently as any was present, and when present was in the judgment of the observers no aid to making this measurement. The average error for all observers in these measurements ranged from 15% to 77% for the different sounds used. In general, the short sounds were overestimated, the long ones underestimated.

The auditory imagery itself was very fragmentary. According to the direct observations only a fourth to a half of the total sound could as a rule be recalled in auditory terms. Combining this with the observer's measurements of the sounds from memory, which were in individual instances often 50% too short, the indication is that the auditory imagery must have been often extraordinarily incomplete. In many individual cases direct observation verified this conclusion. The course of the auditory imagery was decidedly irregular, both with reference to its temporal continuity and with reference to the parts of the sounds it represented. It could not as a rule be voluntarily controlled directly, but only through the motor processes, or through visual imagery in some instances. Through these aids the sound was recalled fragment by fragment, leaving usually large gaps to be filled in by motor representatives alone.